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Original Article

Fish consumption on the Amazon: a review of biodiversity, hydropower and food security issues

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(With 1 figure)

Abstract

The lack of knowledge about the majority of fish species harvested in Amazonian small-scale fisheries, in association with impacts from hydroelectric power plants, may lead to biodiversity loss and a decrease in the protein food supply for riverine Amazonians. This study uses existing datasets on fisheries and riverine developmental projects to infer effects associated with fish losses where actual data and outcomes are not available. The targeted fish species' status may be regarded as either threatened or there being no knowledge of their conservation requirements, biology or ecology. Among the 90 Amazonian fish species that are the most important for the diet of the riverine fishers, 78% are not assessed or their biological information is unknown, according to the IUCN Red List. Consequently, the effects created by the thoroughly disregarded trade-off between energy generation and food security in the planning of Amazonian land use have been worsened by the lack of biological and ecological information on fish species.

Keywords: small-scale fisheries, Amazon River, caboclos, diet, food security.

Consumo de Peixes na Amazônia: uma revisão sobre biodiversidade, hidrelétricas e segurança alimentar

Resumo

A falta de conhecimento sobre a maioria das espécies alvo de comunidades pesqueiras da Amazonia, associada ao impacto das hidrelétricas pode levar ao descréscimo da biodiversidade e na disponibilidade de proteína para os ribeirinhos da Amazônia. As espécies alvo são vulneráveis ou pouco conhecidas em sua biologia ou ecologia. Dentre 90 espécies de peixes importantes na dieta dos ribeirinhos, 78% não são estudadas ou sua biologia é desconhecida, de acordo com a lista da UICN. Dessa forma, os efeitos criados pela negligenciada relação de custo e benefício entre a produção de energia e a segurança alimentar no planejamento da Amazônia tem ainda piorado a situação de desconhecimento sobre as espécies de peixes.

Palavras-chave: comunidades pesqueiras artesanais, Rios da Amazônia, caboclos, dieta, segurança alimentar.

1. Introduction

The Amazon River basin is one of the most biodiverse basins in the world for freshwater species, being, for instance, a known habitat for 2,320 fish species, including 1,488 endemic ones (Abell et al., 2008; Winemiller et al., 2016). Historically, these rich waters have provided fish that help maintain ecological, cultural and economic aspects of Amazonian livelihoods (Begossi and Braga, 1992; Begossi, 2014; Begossi et al., 2004, 2012a,b,c; Hallwass et al., 2011; Hallwass and Silvano, 2016). Most Amazonian fishing is done by small-scale fishers, predominantly from the Caboclo culture (descendants of indigenous Brazilians, Portuguese colonizers and immigrants from the Northeastern Brazil). Many investigations have focused on the Caboclo's anthropology and ecology, such as the classical studies by Moran (1996), Nugent (1993), and Wagley (1974).

Caboclo fishers' diets rely heavily on fish protein, and their livelihoods on the supply of fish to local and regional markets (Silva and Begossi, 2009; Isaac et al., 2008; Sarti et al., 2015). Therefore, Caboclo fishers affect and are affected by the availability of freshwater resources and by fish diversity. The observed decline of fishing resources, caused by pollution, habitat destruction, overfishing and river dams for hydropower projects (Pauly et al., 2002; Welcomme et al., 2010; Hallwass et al., 2013; Winemiller et al., 2016), will increase food insecurity of fish dependent communities. Such a decline has already been observed in African countries (Mcclanahan et al., 2015).

Specifically, hydropower dam construction is rapidly expanding in major river basins around the globe, as countries with emerging economies seek to supply their energy demands without the use of fossil fuels (Zarfl et al., 2014; Winemiller et al., 2016). For instance, more than 450 new dams are under construction or proposed in the Amazon, Congo and Mekong river basins (Winemiller et al., 2016).Throughout the Amazon River Basin there are 416 hydroelectric plants operating or under construction, with another 334 proposed or planned (Winemiller et al., 2016). The Brazilian plan for energy production alone encompasses 58 hydroelectric plants on the largest Amazonian rivers (Kahn et al., 2014).

Besides the impacts caused by the construction and functioning of hydroelectric dams themselves, the electricity transmission networks also create biodiversity impacts by increasing the development of roads, which are the key driver of deforestation in the Amazon (Fearnside, 2015). However, there is little sign that such concerns are being considered by development agencies. For example, the Brazilian government stated the intention to significantly increase electricity grid interconnections for energy distribution (Molle et al., 2010) and to provide additional 10,632 MW of installed generation capacity through future dams by 2023 (Tolmasquim, 2007).

There are many well-known negative consequences of dam development, including: displacement of people; deforestation due to flooding and increased road access for other developments; changes in waterflow, nutrients and sediments impacting downstream terrestrial and aquatic ecosystems including farmlands; and loss of fish (Fearnside, 1999, 2004, 2016; Molle et al., 2010; Orr et al., 2012; Hallwass et al., 2013; Tolmasquim, 2014; Benchimol and Peres, 2015; Winemiller et al., 2016). Dam impacts on aquatic fauna, including fish, result in the blockage of migratory routes essential for the life cycle of many fish species, fragmentation of river connectivity, alteration of physical-chemical structure of the river causing changes in fish communities, as well as local extinctions and a reduction in the abundance of fish species (Petrere Junior, 1989; Zhong and Power, 1996; Ponton and Vauchel, 1998; Barthem et al., 1991; Merona et al., 2001; Gehrke et al., 2002; Petesse and Petrere Junior, 2012; Hallwass et al., 2013).

Many of these impacts are not correctly identified in impact assessment reports, and if identified, decision-makers often ignore negative implications of proposed hydropower developments for reasons of corruption, culture or politics (Fearnside, 1999; Solarte et al., 2008; Isaac et al., 2015; Winemiller et al., 2016). Even in the relevant literature, the impacts of hydroelectric plants on riverine fishing communities are almost absent. One approach to identifying the impacts on such riverine peoples is by considering the changes to the fish fauna, the possible changes in peoples' selective methods of fishing and on their food intake. For example, in the Araguaia-Tocantins system, a heavily impacted region since the 1970's, the livelihoods of about 44,000 people are expected to be affected by the 27 planned dams (Carneiro and Souza, 2009).

Besides developmental projects, overfishing has also affected the biodiversity of various aquatic ecosystems (Pauly et al., 2002; Jackson et al., 2001; Myers and Worm, 2003; Worm et al., 2006). In marine costal areas for instance, studies based on interviews with older fishers indicate that fish catch was higher in the past (Pauly, 1995; Ainsworth et al., 2008). Historical and archaeological studies have shown the occurrence of higher fish abundance in the remote past, which highlights the importance of fish to ancient populations (Pinnegar and Engelhard, 2007; Prestes-Carneiro et al., 2015). One archaeological study indicated that fish fauna accounted for more than 75% of the vertebrate species recovered in an ancient (750 to 1020 A.D.) settlement of indigenous populations in the Central Brazilian Amazon (Prestes-Carneiro et al., 2015). In spite of long lasting importance of fish to ensure food security of human populations (Bené et al., 2015, 2016; Mcclanahan et al., 2015), few studies have shown a link of fish species consumption to food security. Small-scale fisheries (SSFs) ensure income for millions of people worldwide, especially in developing countries (Andrew et al., 2007; De Graaf et al., 2011). In such countries, while fishing may not guarantee large cash incomes, it helps prevent livelihoods of deprivation and poverty (Bené, 2006). Besides, most of the fish caught by SSFs is for direct human consumption (food security) with little discard and reduced costs compared to large-scale commercial fisheries (Pauly, 2006). However, SSFs remain largely underreported and underestimated (Welcomme et al., 2010; De Graaf et al., 2011; Bartley et al., 2015).

Freshwater fish catch is about one seventh of that of marine fish globally (2013) (Food and Agriculture Organization, 2013a). Fish provide 6.5% of global protein, although in Brazil this figure is estimated at only 2.9% (2011) (Food and Agriculture Organization, 2011). In Brazil, fisheries provide 62% (2013) of the fish supply (Food and Agriculture Organization, 2013b), the remaining being provided by aquaculture. Yet for Amazonians fish comprise a major portion of their diet. The average quantity of fish eaten in the Amazon is 462 g.person^{-1}.day^{-1} or 169 kg.person^{-1}.year^{-1} (Isaac et al., 2015). (Table 1). Further, in places such as the Lower Amazon (n=586 records of meals), Lower Purus (n= 341), and Trombetas (n=850) while a wide variety of animal protein sources, such as cayman, canned meat, beef, game meat, chicken egg, pork, poultry, turtle and turtle egg were recorded, fish correspond to 64-76% of the weight of the animal protein intake (Isaac et al., 2015).

In the Negro River, fish account for 75% of the animal protein locally extracted or farmed and for 57%of the total animal protein consumed (in 482 meals recorded) (Silva and Begossi, 2009). However, within nutrition transitional systems, there are records of people starting to acquire and rely on processed and imported food rather than fish. Such a transition has been observed, for example, at Ituqui Island (Amazon River, Santarém, Pará State) (Food and Agriculture Organization, 2013a) and at the Solimões River (Dugan et al., 2002). Given the value of fish in the diets of local people and the risks associated to transitions to other types of food, it is important to raise the question of whether there is enough knowledge to manage Amazonian fish species sustainably.

In this study, we investigate the possible impacts of current fish loss on the food security of riverine inhabitants and livelihoods of small-scale fishers in the Brazilian Amazon. We focus on the rivers Juruá (123), Negro (66), and Araguaia-Tocantins sub-system (328) (Figure 1, Table 1). Our main goal is to conduct a meta-analysis of data collected over 11 years for fish species preferred and consumed by scattered riverine small-scale inhabitants of the Amazon (n=517 interviews) (Figure 1), to investigate potential relationships between the fish species consumed and those that are threatened by dam developments.

2. Methods

This study was based on a compilation of interviews on riverine communities in the Brazilian Amazon (Araguaia, Tocantins, Negro and Jurua rivers, n=517 interviews, Figure 1) at different periods from 1987 to 1998. These studies were conducted in earlier projects coordinated by one of the authors (AB) and data are deposited in archives at the Fisheries and Food Institute (Appendix A). Parts of these data have been previously published (Begossi and Garavello, 1990; Begossi and Braga, 1992; Begossi and Figueiredo, 1995; Begossi et al., 1999, 2012a,b,c; Silva and Begossi, 2009).

For this study, we compiled data about the first two items cited by fishers when they were asked about *the fish species they consumed the most*, referred herein respectively as "F1 (fish most consumed) and F2 (second most consumed fish, Table 2). Details of the methods and of fish taxonomic identification, along with other information of the areas and of the communities studied can be found in previous studies (Begossi and Garavello, 1990; Begossi and Braga, 1992; Begossi and Figueiredo, 1995; Begossi et al., 1999,

Table 1. Fish consumption at some Amazonian localities according to the literature. All data shown in the references converted to grams/per capita/day.

Fieldwork Date	Grams per capita day	Locality	Reference
1993-1995	369	**Lower Amazon** Monte Alegre	Cerdeira et al. (1997)
1992-1994	550	**Low Solimões/High Amazon region** Pesqueiro Paciência Aruanã Marimbá	Batista et al. (1998)
1991-1993	243	**Madeira River** 180 km from Porto Velho	Boischio and Henshel (2000)
	137 [4.1 kg.hab.month]	**Lower Tocantins** Ituquara village	Mérona et al. (2001)
	155 [4.6 kg.hab.month]		Shrimpton and Giugliano (1979)
1981-1982	98 [35.7 kg.hab.year] 45 [(124 grams per capita day) 52 (143 grams per capita day) 7.0 (19 grams per capita day) 7.3 (20 grams per capita day)	**Tocantins** **Cametá** **Mocajuba** **Ituquara** **Tucuruí** **Marabá**	Mérona et al. (2010) [The Tucuruí and Marabá sites are upstream of the dam].

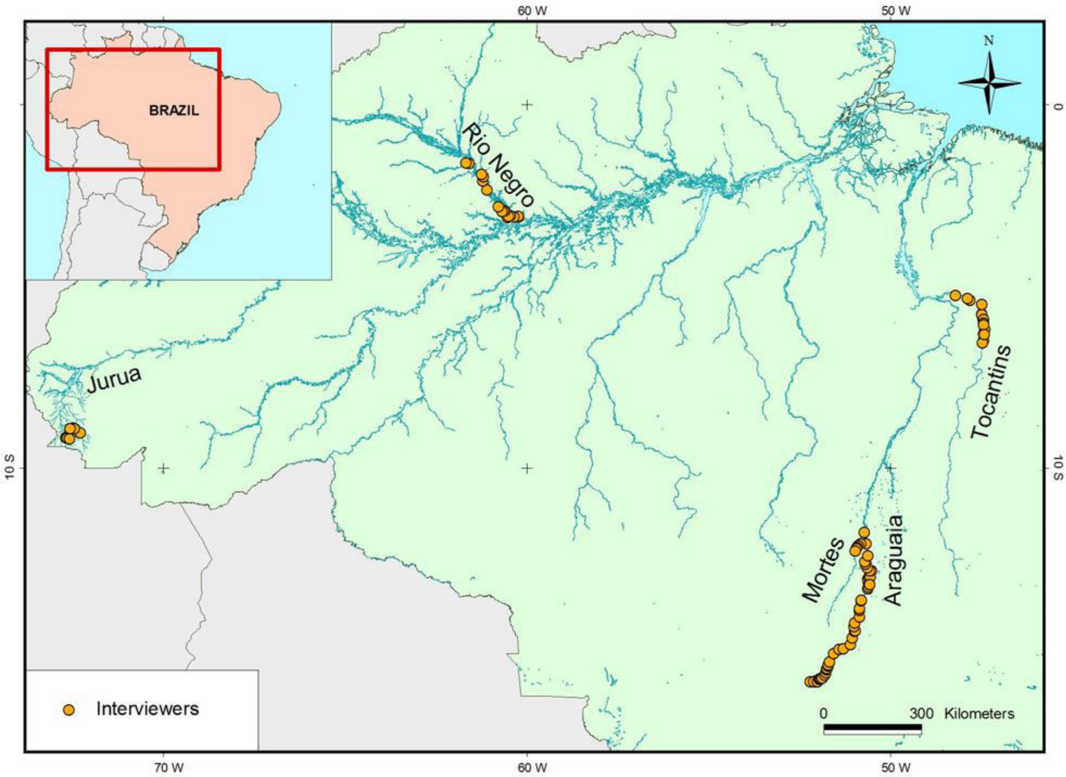

Figure 1. Brazilian Amazon showing the locations of interviews with riverine small-scale fishers (Caboclos).

Table 2. The most important fish cited as consumed by Amazonian riverine families. Results from interviews with Amazon small-scale riverine fishers (see Table 3 for scientific names of fish species) (10% citations or more); n= number of interviews; F1=fish cited first in interviews; F2= fish cited second in interviews.

Amazonian rivers/Fish	ARAGUAIA & MORTE n=97	TOCANTINS n=231	NEGRO n=66	JURUA n=123	TOTAL n=517
Mandi	26 (F1)	23 (F2)		31 (F1) 30 (F2)	16 (F1) 19 (F2)
Tucunare	23 (F1) 12 (F2)		23 (F1) 20 (F2)		
Piranha	15 (F1)		16 (F2)		
Piau	20 (F2)	12 (F2)			
Curimata		52 (F1)			24 (F1)
Branquinha		13 (F2)			
Pacu		11 (F2)	17 (F1) 16 (F2)		
Jaraqui			29 (F1) 14 (F2)		
Cara			11 (F1) 12 (F2)		
Bode				51 (F1) 15 (F2)	12 (F1)
Surubim				13 (F2)	

2012a,b,c, 2017; Silva and Begossi, 2009). We assessed the current conservation status of the most cited fish at the IUCN website and at the latest Brazilian Red List, published in November 2014 (IUCN, 2014).

3. Results

From the 517 interviews, the fish most cited as consumed in the Amazonian rivers Araguaia and Mortes, Tocantins, Jurua and Negro were Curimata (*Prochilodus nigricans*) and Mandi (*Pimelodella*, *Pimelodus*, among other spp.). Tucunaré (*Cichla* spp.) was important in Araguaia, Mortes and Negro, Jaraqui (*Semaprochilodus* spp.) was important at the Negro River, and Bode (species of Loricariidade) was important at the Jurua river and its tributaries (Table 2). In another set of interviews in 1987-1988 at the Tocantins river banks (n=233 interviews) 65 fishers mentioned that Pacu-manteiga (*Mylossoma duriventre*), an important local fish consumed, decreased in abundance due to the Tucuruí dam.

The IUCN Red List includes 90 species of the 95 species that were cited as the most important by the riverine fishers. Most of them (78%) have not been assessed and 10% are of least concern (NA) (Table 3). Therefore, we have almost no knowledge on the conservation status of the most important fish for the food security of Amazonian fishers.

4. Discussion

Our results highlighted the almost complete lack of knowledge on freshwater fish important for the food security of Amazonian people. This knowledge gap about the vulnerability of fish can negatively affect and compromise the food security of those Amazonian human populations who highly depend on fish as a source of protein (Batista et al., 1998; Isaac and Almeida, 2011; Begossi et al., 2012b; Lopes et al., 2015). Capture fisheries improve nutrition and food security, besides reducing poverty, in tropical developing countries (Bené et al., 2016). A decrease in the supply of fish as a food source may have indirect consequences for these populations, their livelihoods and their biodiversity rich ecosystems. In Brazil, the food habits of riverine people can change, by including more processed and industrialized items, such as chicken nuggets, pasta, canned meat, among others. Such food items may be nutritionally poor and create a dependence on external food sources (Silva and Begossi, 2009). A decrease in the supply of fish as a food source may increase the use of land for agriculture and hence the rate of deforestation (Orr et al., 2012). This would not only threaten the terrestrial biodiversity but could also exacerbate the current conflicts between fishers and managers of protected tropical forests (Lopes et al., 2013; Begossi et al., 2011). Of particularly interest here are the contrasting cases of the Negro and Araguaia rivers. In the Negro River (52 meals), the reported consumption of animal protein showed that locally caught fish responded for 75% of their diet, whereas in Araguaia fish responded for only 10% of all animal protein consumed (Begossi et al., 2000).

The increased exploitation of large, slow-growing and more vulnerable fish species has caused drastic reduction in the populations or even local extinction of these fish, and they tend to be replaced by less valuable and smaller fish in multi-species fisheries (Welcomme, 1999). This pattern of sequential overfishing in tropical fisheries, which is usually driven by an increase demand for fish, have been described as the ‘fishing down’ process in freshwaters (Welcomme, 1999; Welcomme et al., 2010), and as ‘fishing down the food web’ in marine ecosystems (Pauly et al., 1998). ‘Fishing down’ implies a major reduction in the size of the fish caught (either smaller species or smaller individuals of the same species) (Welcomme et al., 2010). The ‘fishing down the food web’ implies an overall decrease in the mean trophic level of exploited fish, as larger piscivorous are depleted (Pauly et al., 1998, 2002), although recent evidence has indicated that the sequential overfishing can be more strongly related to the net value of fishing resources than the trophic level of captured species (Sethi et al., 2010).

Ancient Amazonian indigenous people consumed at least 37 taxa of fish species. The larger fish species consumed by these ancient populations (Pirarucu, *Arapaima gigas*, and Tambaqui, *Colossoma macropomum*) (Prestes-Carneiro et al., 2015) are currently considered overfished in some regions of the Amazon (Smith, 1985; Garcia et al., 2009; Castello et al., 2013). On the other hand, small fish, such as Mandi, Acari (or Bodes, Loricariidae), Jaraqui, Curimatá, Piau and Tucunaré, were consumed in lower frequencies by the ancient Amazonians (Prestes-Carneiro et al., 2015) (Table 1). The change in the main fish species consumed over time indicates a reduction in the availability and abundance of the large and preferred fish species, which can lead to vulnerability in the food security of riverine peoples who depend on fish for protein intake. The larger fish usually provide more assimilated energy (more biomass) and comparatively demand less processing time to be consumed (fewer or larger spines), tending to be thus more valuable and preferred by fishers (Begossi et al., 2012b).

Governmental plans assigned to protected areas are often in conflict with fish biology researchers, fishery participants and fishers. Furthermore, most of the existing protected areas in Brazil in general (Lopes et al., 2013) or in the Brazilian Amazon (Castello et al., 2013, Junk et al., 2007) have been planned for the protection of terrestrial ecosystems, and have not properly considered for the protection of aquatic biodiversity, fishing resources and local fishing communities. Besides, recent political initiatives by the Brazilian Government (Brazilian Red List and spawning closed seasons) (Pinheiro et al., 2015), might affect threatened species and species where knowledge is almost absent (Table 3). In Brazil, the migratory fish such as Jaraqui (*Semaprochilodus* spp.), Matrinchã (*Brycon sp.*), Dourada (*Brachyplatystoma rousseauxii*), and Filhote (*Brachyplatystoma filamentosum*) may be increasingly threatened by the construction of dams in the upstream reaches of large rivers (Barthem et al., 1991; Hallwass et al., 2013; Hallwass and Silvano, 2016; Winemiller et al., 2016).

To reverse the observed trend of increasing threats to fish and fishers, we suggest that more attention be devoted to fisheries management and conservation agendas to protect and manage those often neglected fish that are an important food source. This may be achieved by working together and cooperating with the fishers themselves, who have detailed knowledge about fish biology (Silvano et al., 2006, 2008; Silvano and Begossi, 2012; Leite and Gasalla, 2013), and can help to protect fish stocks through co-management

Table 3. Conservation status of fish consumed in coastal (Atlantic Forest) and inland (Amazon Forest) areas of Brazil [partial information published (Part of this material previously published (Winemiller et al., 2016; Begossi, 2014; Hallwass et al., 2011; Pinnegar and Engelhard, 2007; Prestes-Carneiro et al., 2015; Béné et al., 2015).

Popular name	Scientific name	Species "spp."	Data Base[1]			
			IUCN	Population trend (IUCN)	Brazilian Red List[2]	Ordinance Nº 445/2014 (Canceled)[3]
Bode, Bodó ou Acari	*Ancistrus* spp.	*A.dolichopterus*	LC	stable		
		A.cryptophthalmus				EN
		A.minutus				EM
		A.formoso				VU
	Apistoloricaria spp.		NA		NA	NA
	Glyptoperichthys gibbiceps		NA		NA	NA
	Glyptoperichthys punctatus		NA		NA	NA
	Hemiancistrus niveatus		NA		NA	NA
	Hypoptopoma gulare		NA		NA	NA
	Hypostomus emarginatus		NA		NA	NA
	Hypostomus plecostomus		NA		NA	NA
	Hypostomus spp. (*H. hemiurus*)		LC	stable	NA	NA
	Lamontichthys filamentosus		NA		NA	NA
	Limatulichthys punctatus		NA		NA	NA
	Liposarcus pardalis		NA		NA	NA
	Loricaria cataphracta		NA		NA	NA
	Loricaria cf. similima		NA		NA	NA
	Loricariichthys maculatus		NA		NA	NA
	Panaque nigrolineatus		NA		NA	NA
	Panaque spp.		DD	unknown	NA	NA
	Peckoltia bachi		NA		NA	NA
	Peckoltia brevis		NA		NA	NA
	Planiloricaria cryptodon		NA		NA	NA
	Pseudacanthicus spinosus		NA		NA	NA
	Spatuloricaria evansii		LC	stable	NA	NA
	Sturisoma robustum		NA		NA	NA
	Pterigoplichthys sp.		NA		NA	NA
	Pseudacanthicus sp.		NA		NA	NA
Branquinha	*Curimata inornata*		NC		NA	NA
	Curimata vittata		LC	stable	NA	NA
	Cyphocharax spp.				NA	NA
	Potamorhina altamazonica (chamada de mocinha no Juruá)		NC		NA	NA
	Potamorhina latior		NC		NA	NA
	Potamorhina pristigaster		NC		NA	NA
	Psectrogaster amazonica (chamada de casca grossa no Juruá)		NC		NA	NA
	Psectrogaster rutiloides (chamada de casca grossa no Juruá)		NC		NA	NA

[1]Legend: NA = Not Assessed; DD = Data Deficient; LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered; EW = Extinct in the Wild; EX = Extinct; [2]Based on Normative Instruction Nº 5, May 21th, 2005; [3]Ordinance of Ministry of the Environment Nº 445, December 17th, 2014 – Canceled (Pinheiro et al., 2015).

Table 3. Continued...

Popular name	Scientific name	Species "spp."	Data Base[1]			
			IUCN	Population trend (IUCN)	Brazilian Red List[2]	Ordinance Nº 445/2014 (Canceled)[3]
	Psectrogasteressequibensis		NC		NA	NA
	Curimata amazonica		NC		NA	NA
	Curimatella immaculata (saburu)		NC		NA	NA
	Steindachnerina spp. (S. amazonica), (saburu)		LC	stable	NA	NA
Curimatá	*Prochilodus nigricans*		NA		NA	NA
Jaraqui	*Semaprochilodus brama*		NA		NA	NA
	Semaprochilodus insignis		NA		Overexploited or Threatened overexploitation	NA
	Semaprochilodus taeniurus		LC	stable	Overexploited or Threatened overexploitation	NA
Mandi	*Cheirocerus goeldii*		NA		NA	NA
	Megalonema platycephalum		NA		NA	NA
	Pimelodella cristata		LC	stable	NA	NA
	Pimelodella gracilis		NA		NA	NA
	Pimelodina flavipinnis		NA		NA	NA
	Pimelodus aff. altissimus		NA		NA	NA
	Pimelodus blochii (mandi cabeça de ferro)		NA		NA	NA
	Pimelodus spp.					
		P.halisodous				VU
		P. joannis				VU
		P. stewartii				VU
	Hassar wilderi		NA		NA	NA
	Megalodoras irwini		NA		NA	NA
	Trachydoras trachyparia		NA		NA	NA
	Centromochlus heckelli		NA		NA	NA
	Centromochlus sp. (*C. reticulatus*)		LC	stable	NA	NA
	Luciopimelodus sp.		NA		NA	NA
	Cheirocerus eques		NA		NA	NA
Pacu	*Metynnis hypsauchen*		NA		NA	NA
	Metynnis lippincottianus		NA		NA	NA
	Myleus rubripinnis		NA		NA	NA
	Myleus schomburgkii		NA		NA	NA
	Myleus spp.		NA		NA	NA
	Myleus torquatus		NA		NA	NA
	Mylossoma aureum		NA		NA	NA
	Mylossoma duriventre (pacu manteiga)		NA		NA	NA
	Myleus pacu		NA		NA	NA
Piau	*Abramites hypselonotus*		NA		NA	NA
	Anostomoides laticeps		NA		NA	NA
	Laemolyta petite		NA		NA	NA

[1]Legend: NA = Not Assessed; DD = Data Deficient; LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered; EW = Extinct in the Wild; EX = Extinct; [2]Based on Normative Instruction Nº 5, May 21th, 2005; [3]Ordinance of Ministry of the Environment Nº 445, December 17th, 2014 – Canceled (Pinheiro et al., 2015).

Table 3. Continued...

Popular name	Scientific name	Species "spp."	Data Base[1] IUCN	Population trend (IUCN)	Brazilian Red List[2]	Ordinance Nº 445/2014 (Canceled)[3]
	Laemolyta spp.		NA		NA	NA
	Laemolyta varia		NA		NA	NA
	Leporinus affinis		NA		NA	NA
	Leporinus agassizii		NA		NA	NA
	Leporinus falcipinnis		NA		NA	NA
	Leporinus fasciatus		NA		NA	NA
	Leporinus friderici (piau cabeça-gorda)		NA		NA	NA
	Leporinus spp. (*L. granti*)		LC	stable	NA	NA
	Leporinus trifasciatus		NA		NA	NA
	Schizodon fasciatus		NA		NA	NA
	Schizodon vittatus (piau vara)		NA		NA	NA
Piranha	*Pristobrycon striolatus*		NA		NA	NA
	Pygocentrus nattereri (piranha vermelha)		NA		NA	NA
	Serrasalmus eigenmanni		NA		NA	NA
	Serrasalmus gouldingi		NA		NA	NA
	Serrasalmus marginatus		NA		NA	NA
	Serrasalmus rhombeus (piranha preta)		NA		NA	NA
	Serrasalmus spilopleura (piranha preta)		NA		NA	NA
Tucunaré	*Cichla temensis* (tucunaré comum, tucunaré açu)		NA		NA	NA
	Cichla ocellaris (tucunaré pitanga)		NA		NA	NA
	Cichla kelberi		NA		NA	NA
	Cichla monoculus		NA		NA	NA
	Cichla orinocensis		NA		NA	NA
	Cichla pinima		NA		NA	NA

[1]Legend: NA = Not Assessed; DD = Data Deficient; LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered; EW = Extinct in the Wild; EX = Extinct; [2]Based on Normative Instruction Nº 5, May 21th, 2005; [3]Ordinance of Ministry of the Environment Nº 445, December 17th, 2014 – Canceled (Pinheiro et al., 2015).

systems (Defeo and Castilla, 2005; Gelcich et al., 2008; Lopes et al., 2011; Silvano et al., 2014). A first step would be to reveal those fish most important to sustain livelihoods and food security; to identify those most threatened; and then devise policies to maintain these fish species before they are gone. For several years, Brazilian researchers have been stressing the impacts that hydroelectric power plants have on fish. Most important are those that cause a sharp decrease in the species richness (for example, in Tucuruí Reservoir about 50% of the fish species have been lost), and those that have a drastic impact on migratory species (Petrere Junior, 1989, 1996; Barthem et al., 1991; Kahn et al., 2014). More recently, a study has shown that the environmental impact assessments are very limited in Brazil, with poor methodologies and imprecise requirements, preventing the identification of impacts and possible mitigating actions (one example approached the Belo Monte Dam) (Ritter et al., 2017). However, more than 10 years ago researchers have claimed on the impacts hydroelectric could cause (Tundisi, 2007). Giving the scale and timing of change happening in Amazonian rivers, action is needed now to ensure that our rivers can continue to feed riverine people.

5. Conclusions

Our concluding remarks summarize the evidence and observations on the association between biodiversity loss and increased food insecurity, as follows:

1 Hydropower development in the Amazon could negatively affect river fisheries.

2. While the national diet in Brazil has only a small portion of freshwater fish (1.5%), the protein diet of the riverine Amazonian Caboclos small-scale fishers (based on research in communities of 773,000 estimated people in total/IBGE) is substantially dependant on riverine fish for protein (around 70% of protein in their diet).

3. The Caboclos target particular species when fishing.

4. The majority (78%) of the targeted fish species are either regarded as 'not known' or threatened. This is a very important. consideration, since it is likely that some species could to disappear before we will have appropriate knowledge for their conservation.

5. The targeted fish species might be vulnerable as a result of many individual and combined impacts, such as overfishing and multiple hydropower dam development.

6. In this review we reinforce suggestions that hydropower development (along with other development pressures) in the Amazon may threaten the food security of the Caboclos in Brazil. The data of the main fish species consumed by the Caboclos show that impact from dams could potentially affect the main species consumed and therefore the food security of riverine Caboclos.

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Appendix A. Study sites, archive number of interviews deposited at the Fisheries and Food Institute (2015), Santos, SP, at Unisanta, Santos, SP.

The grant # and funding agency is shown.

ARCHIVE NUMBER/FIFO[1]	STUDY SITE	FUNDING AGENCY
PAJUR 007	ALTO JURUÁ ACRE AM	FAPESP 1998/02619-8/ Project F. MacArthur 92/21848 Coords. Brown, Almeida & Cunha (UNICAMP)
PDRPTO 008	TOCANTINS RIVER AM	R. P.: FAPESP [1994/6258-7] CNPq [400.185/95-4] TO: 1987/ 1988: THEMAG/ELETROBRAS
PTOCETNO 008	TOCANTINS RIVER AM	TO: 1987/ 1988: THEMAG/ELETROBRAS
PTOCGOMA 008	TOCANTINS RIVER AM	TO: 1987/ 1988: THEMAG/ELETROBRAS
PDDARA 009	ARAGUAIA RIVER AM	FAPESP [1996/1036-1]
PARA 009	ARAGUAIA RIVER AM	FAPESP [1996/1036-1]
PDRNMA 018	QUEST RIO NEGRO AM	FAPESP 1998/16160-5

[1]Fisheries and Food Institute.

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In the article "**Fish consumption on the Amazon: a review of biodiversity, hydropower and food security issues**", DOI: https://doi.org/10.1590/1519-6984.186572, published ahead of print on Oct 29, 2018 in Brazilian Journal of Biology, in the Acknowledgements the article:

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It should be read:

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In memoriam Benedito D. do Amaral.